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(54) MANUFACTURE OF ISOTROPIC BOND MAGNET

(57)Abstract:
PURPOSE: To provide a method of manufacturing an isotropic bond magnet of rare earth metal, iron, cobalt, and boron high in strength and excellent in magnetic properties.
CONSTITUTION: Resin binder is added to magnetic powder composed of rare earth metal, iron, cobalt, and boron and formed through a quench solidifying method, resin binder-loaded magnetic powder is compression-molded by a pressure of over 120kgf/mm2, a molding die is released from a clamping force once and clamped again by a clamping pressure over a molding pressure, a molded magnet is released from the molding die and heated to harden resin. At this point, 1 to 3% by weight of resin binder is added to magnetic powder 30 to 155μm in average grain diameter.

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CLAIMS

[Claim(s)]

[Claim 1] In the approach the presentation made by the rapid solidification method presses the magnetic powder of a rare earth metal, iron, and a cobalt boron system using a resin bond agent It is filled up with the powder which made the resin bond agent adhere to magnetic powder in a force plunger, and is 2 a 120 kgf/mm pressure. The manufacture approach of the isotropic bond magnet characterized by pressing above, once releasing a pressure, heating after compressing and releasing from mold by said compacting pressure and the pressure more than equivalent again, and hardening resin.

[Claim 2] The manufacture approach of the isotropic bond magnet according to claim 1 characterized by using the powder which coated with 1 - 3 % of the weight of resin binders the magnetic powder whose mean particle diameter is 30-155 micrometers.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention can be used for the stator of a motor, Rota, etc. about the manufacture approach of the isotropic bond magnet which combined the RTB system magnetism powder with which a presentation consists of a rare earth metal, iron, and cobalt boron by resin.
[0002]
[Description of the Prior Art] The isotropic bond magnet of an RTB system has outstanding magnetic properties compared with the conventional hard ferrite and the alnico magnet, and a production process also becomes easy and it has the advantageous description in respect of cost in order to give neither not using expensive Sm nor a magnetic anisotropy, although it is inferior a little by magnetic properties compared with the Sm-Co system bond magnet of an anisotropy. As an application, it is applied to the stator for motors, such as a power tool and a hard disk, etc.
[0003] The manufacture approach of an isotropic bond magnet manufactures the magnetic powder of an RTB system by the rapid solidification method and the crushing method, mixes the nature material of organic which is a binder, minerals material, or a low-melt point point metal like solder to that magnetic powder as indicated by JP,59-211549,A, and it is this mixed powder about 110 kgf(s)/mm 2 It presses by the pressure of extent. The consistencies obtained are about 6.0 g/cm3. It is extent (about 80% of density ratios).
[0004] Moreover, there is a proposal of carrying out densification of the Plastic solid and raising magnetic properties, by coating a magnetic powder front face with resin of a certain kind, and making it fluid good powder like a JP,1-281707,A publication, that it is easy to slide on this powder particle at the time of shaping. By the way, also in present condition quality, although it is usable, as for the magnetic properties of an isotropic

bond magnet, much more improvement in a property is desired for the improvement in an output of a motor, and power consumption reduction. For that purpose, since it depends for magnetic properties on the consistency of a Plastic solid, it is necessary to raise the space factor of the magnetic powder occupied to a Plastic solid.

[0005] Moreover, the application of the member which exercises like Rota for motors on the other hand requires higher mechanical strength. However, the magnetic powder of an RTB system crushes the ribbon-like material produced using rapid solidification equipment with a stamp mill etc., the shape of flat is carried out, HV 700-1000 also has hardness, and a powder configuration is very hard compared with HV 100-250 of the usual powder for powder metallurgy. Moreover, since this magnetic powder contains activity Nd, it not only causes degradation of powder, but the powder of a small particle size tends to produce oxidation reaction in atmospheric air and there is fear of ignition, the mean particle diameter of commercial powder is about 155 micrometers and a coarse thing. Therefore, a moldability is bad remarkable powder and made improvement in densification and reinforcement difficult.

[0006]

[Problem(s) to be Solved by the Invention] This invention tends to offer the manufacture approach of an isotropic bond magnet of having outstanding mechanical characteristics and magnetic properties, and the fabricating method for the ability to improve a mechanical strength also by the same product consistency especially.

[0007]

[Means for Solving the Problem] In the approach the presentation made by the rapid solidification method presses the magnetic powder of a rare earth metal, iron, and a cobalt boron system using a resin bond agent in order that this invention may solve the above-mentioned technical problem It is filled up with the powder which made the resin bond agent adhere to magnetic powder in a force plunger, and is 2 a 120 kgf/mm pressure. Press above and a pressure is once released. After compressing and releasing from mold by said compacting pressure and pressure more than an EQC again, the manufacture approach of the isotropic bond magnet characterized by heating and hardening resin is offered.

[0008] Moreover, in the aforementioned manufacture approach, it is characterized by using the powder which coated with 1 - 3 % of the weight of resin binders the magnetic powder whose mean particle diameter is 30-155 micrometers. An epoxy resin is suitable for the resin which is a binder. After kneading [solvent] resin with magnetic powder, it dries, and it is made into the shape of a cake, crushes it, and prepares it to the powder for shaping.

[0009] Moreover, in order to make mean particle diameter of magnetic powder small The resin bond agent and solvent of commercial magnetic powder and the specified quantity are put into the bessel of a vibration mill with grinding media. After carrying out predetermined time vibration where the inside of bessel is permuted by the inert gas gas ambient atmosphere, and grinding magnetic powder, It considers as the magnetic powder with which it considered as the shape of a cake which carries out volatilization removal of the solvent contained in the suspension of the magnetic powder obtained in an inert gas ambient atmosphere, and consists of magnetic powder and resin, and the cake was crushed in the inert gas ambient atmosphere, and coating of the resin was carried out.

[0010] As the shaping approach, the usual metal mold equipment by the dice and punch is used. Powder is filled up with a predetermined pressure into the mold made from elastic bodies which carry out the first shaping and the 2nd step of shaping, such as an approach and rubber. CIP -- the first rank -- the approach which releases from mold by carrying out the 2nd step of pressurization after operating orthopedically and removing a pressure -- or this preforming object after filling up a dice with an inner hole with a taper with powder and compressing by punch -- a side with the large inner hole dimension of a dice -- punch -- moving -- the first rank -- after canceling the pressure concerning a Plastic solid, there is the approach of carrying out the 2nd step of pressurization and releasing from mold from a side with the large inner hole dimension of a dice.

[0011] Resin hardening processing of a Plastic solid is performed by resin's hardening [temperature] at about 160-180 degrees C, and carrying out time amount maintenance. In addition, in order to prevent oxidation of magnetic powder as much as possible, as for adjustment of powder, compression molding, and heat-treatment, it is desirable to carry out in inert gas ambient atmospheres, such as argon gas.

[0012]

[Function] First, the resin which is a binder affects the reinforcement of a product with the adhesion approach and coating weight. Although powder alligation and the coating method by kneading are mentioned as the adhesion approach, the coating method of reinforcement is higher, and since antioxidizing of the front face of magnetic powder is covered and carried out, it excels.

[0013] The coating weight of resin affects a shaping consistency and the reinforcement of a Plastic solid. Although the amount of resin rises proportionally mostly to coating weight to 2.0 % of the weight, even if the reinforcement of a Plastic solid adheres more mostly than 2.5 % of the weight, it does not rise. On the other hand, the amount of resin

produces a crack in a Plastic solid at less than 1%. Moreover, if a shaping consistency shows maximum with the 1.5 - 2 % of the weight of the amounts of resin and 2 % of the weight is exceeded, it will serve as a fall inclination, and if 3 % of the weight is exceeded, it will fall rapidly. Therefore, the amount of resin is 1.5 - 2.5 % of the weight desirably one to 3% of the weight.

[0014] Next, the grain size of magnetic powder affects the reinforcement and magnetic property of a product. It follows on the reinforcement of a product becoming finer than a case with a mean particle diameter of 155 micrometers marketed, it becomes high gradually, and becomes max by 40 micrometers, and if the reinforcement at the time of 30 micrometers and 155 micrometers shows the almost same value and is finer than 30 micrometers, reinforcement will fall rapidly. Magnetic property is equivalent with a mean particle diameter of 155-40 micrometers in between, and gets worse by less than 30 micrometers. Therefore, 30-155 micrometers of particle diameter of magnetic powder are 40-100 micrometers desirably.

[0015] Next, although it is the shaping approach, in one usual shaping, the consistency of a product rises with the increment in compacting pressure, and reinforcement and magnetic properties are improved in connection with it. However, compacting pressure 250kgf/mm2 A consistency does not rise as for the above. It is the same as that of the former that a consistency rises and reinforcement and magnetic properties are improved in connection with it on the other hand by the increment in welding pressure although it is a double-shot molding method. However, the high property which is not acquired is acquired in 1-time shaping usual in the reinforcement of a product. If an important thing is not more than welding pressure with compacting pressure here, the effectiveness of double-shot molding is not accepting at all. That is, the compacting pressure of the first rank is 2 110 kgf(s)/mm. It is not below different from the case of 1-time shaping at all. Compacting pressure 120kgf/mm2 of the first rank Above, the 2nd step of compacting pressure also becomes equivalent to the first rank, or more than it, and the effectiveness of the improvement in on the strength shows up. for example, the usual 1-time shaping -- pressure 250kgf/mm2 the consistency obtained -- 6.35 g/cm3 -- reinforcement -- 1830 kgf/cm2 It compares with a thing. it is -- It is [the first rank and] the 2nd step 200 kgf(s)/mm, respectively 2 When it fabricates, consistencies are 6.35 g/cm3. Reinforcement is [2130 kgf/cm2, the first rank, and] the 2nd step 250kg/mm, respectively 2 When it fabricates, it is 3 6.40g/mm. Reinforcement is 3000 kgf/cm2. It becomes.

[0016] If this considers the magnetic powder of the shape of flat [with which resin was covered] from the process which carries out pressing, along with the increment in

welding pressure, the space between powder will decrease in number gradually first, and a consistency will rise. If welding pressure is furthermore gone up, while some particles are crushed, a consistency will rise further, but the flat particle is in the bridge condition arranged at random, and even if it increases welding pressure, a consistency will not rise any more. Then, if a pressure is released, springback of the Plastic solid will be carried out and it will produce few clearances between particles. Subsequently, if the 2nd step of pressurization is carried out, it will be arranged by right-angled ** to the pressurization direction, and a consistency will rise, and many of flat particles will be imagined to be those to which reinforcement becomes high when the touch area between particles increases.

[0017]

[Example] [Example 1] It was made by the rapid solidification method the used magnetic powder contains cobalt for iron 67.0% of the weight, and contains 24.6 % of the weight and boron for neodium 1.7% of the weight 5.2% of the weight, and mean particle diameter is 155 micrometers.

[0018] Resin coating melted the epoxy resin to the solvent, and kneaded this solution and magnetic powder by the kneader. Then, the solvent was dried using the thermostat permuted by argon gas, and the magnetic powder front face was coated with the epoxy resin. The amount of resin is 2.0 % of the weight. This powder is used and it is the pressure of the first rank 100 to 300 kgf/mm 2 The fabricated sample was produced.

[0019] Next, metal mold with a somewhat larger inner hole than the metal mold used by the first rank is used, and it is the pressure of the first rank 100 to 250 kgf/mm 2 It is the fabricated test piece a 100 to 250 kgf/mm pressure 2 The 2nd step of shaping was performed. Then, with the thermostat which permuted each of the sample (example of a comparison) fabricated once, and the sample which carried out double-shot molding by argon gas, at the temperature of 160 degrees C, it heated at the temperature of 180 degrees C further for 1 hour, and resin hardening was given for 1 hour. A sample dimension is 10mm in the diameter of 11.3mm, and height.

[0020] Next, the compressive strength of a residual magnetic flux density, a maximum energy product, and sample shaft orientations was measured as a consistency and magnetic properties about each sample. Compressive strength is the maximum in the stress-strain curve Fig. when compressing a test piece by part for 0.5mm/of compression velocity using a compression tester. First, about the property of the sample of 1-time shaping of the example of a comparison, a consistency and the relation of a maximum energy product are shown in the relation between a consistency and compressive strength, and drawing 6 , and the relation between a consistency and a residual

magnetic flux density is shown in drawing 4 at drawing 7 at the relation between compacting pressure and a consistency, and drawing 5 .

[0021] Drawing 4 to compacting pressure 250kgf/mm2 A consistency serves as maximum 6.35 g/cm3, and it turns out that a consistency does not rise even if it applies a pressure more than it. drawing 5 to a consistency, and compressive strength -- a correlation -- it is -- the maximum of compressive strength -- 1830 kgf/cm2 it is . Drawing 6 and drawing 7 show that magnetic property shows such a good property that a consistency is high.

[0022] Next, drawing 1 shows the effectiveness of this invention about the reinforcement of the test piece produced by the double-shot molding method. In addition, the result of the usual 1-time shaping shown in drawing 5 for the comparison was also written together. A white round head shows the value by the usual 1-time shaping, and a black dot is the value of a double-shot molding method. The compacting pressure of a double-shot molding method shows the 2nd step of pressure to the left-hand side of an arrow head the pressure of the first rank, and on the right-hand side of the arrow head.

[0023] The pressure of the first rank is 2 100 kgf(s)/mm. For a test piece, the 2nd step of pressure is 2 150 kgf(s)/mm. It is the reinforcement which can be attained by the usual shaping approach but, and there is no effectiveness of this invention. However, the pressure of the first rank is 2 120 kgf(s)/mm. If it becomes above, reinforcement will improve by leaps and bounds. here -- it should mention specially -- compacting pressure 150kgf/mm2 of the first rank, and the 2nd step of pressure 150kgf/mm2 a test piece -- the usual shaping approach -- pressure 200kgf/mm2 although the test piece and consistency which were produced are the same -- a value with high reinforcement -- being shown -- **** -- 250kgf/mm2 of the further usual shaping approach It is a high value.

[0024] Moreover, it is [the first rank and] 2 250 kgf(s)/mm the 2nd step. What was fabricated is 3000 kgf/cm2 which is 1.6 times the maximum of the compressive strength obtained with a conventional method. It is obtained.

[An example 2] The magnetic powder with which the mean particle diameter by which put the magnetic powder with a mean particle diameter of 155 micrometers used in the example 1, the epoxy resin melted into a solvent, and the ball for grinding into the planet ball mill, and took out in the thermostat permuted by argon gas after carrying out predetermined-time operation, where the inside of a mill is permuted and sealed by argon gas, made dry a solvent, crushed cake-like powder in argon gas, and coating was carried out with an epoxy resin differs produced. The amount of resin is 2.0 % of the weight.

[0025] Next, after putting in metal mold into the argon gas ambient atmosphere and pressing each powder by the double-shot molding method using the adjustable ambient atmosphere molding press, resin hardening processing was carried out like the example 1. compacting pressure -- the first rank and the 2nd step --- 250kgf/mm2 it is . Compressive strength, the residual magnetic flux density, and the maximum energy product were measured about the obtained sample.
[0026] Mean particle diameter and the relation of each measurement result are shown in drawing 2 . Compressive strength becomes high gradually in connection with particle size becoming small, and maximum is shown when mean particle diameter is 40 micrometers. If particle size becomes small from 40 micrometers, reinforcement falls and mean particle diameter shows 30 micrometers and the 155 micrometers of the almost same values. The inclination which will get worse if magnetic property shows an equivalent value and becomes smaller than 40 micrometers while mean particle diameter is 155-40 micrometers is shown.
[0027] Although a property with the mean particle diameter of magnetic powder good [at least 155 micrometers with marketing] is acquired from this, in order to obtain higher reinforcement, it turns out that mean-particle-diameter the order of 50 micrometers is good.
[Example 3] The powder with which the amounts of coatings of an epoxy resin differ was produced by the same approach as an example 1 using magnetic powder with a mean particle diameter of 155 micrometers.
[0028] Next, the 2nd step is [the first rank and] each powder with which the amounts of resin differ 150 kgf(s)/mm 2 After fabricating by the pressure, resin hardening processing was carried out like the example 1, it considered as the sample, and a consistency and compressive strength were measured. The relation between the amount of resin, a consistency, and compressive strength is shown in drawing 3 . If there are few amounts of resin than 1 % of the weight, a crack will be produced in a Plastic solid.
[0029] A fall will become remarkable, if a consistency shows maximum and exceeds 3 % of the weight, while the amount of resin is 1.5 - 2 % of the weight. Compressive strength will rise, if the amount of resin is increased, and even if maximum is shown and it adds more than it at 2.5 % of the weight, it is ineffective. 1 % of the weight or more to which a crack does not come out of the amount of resin from this is required, and it is to 3 % of the weight which a consistency does not make remarkably low. Preferably, it turns out that it is just over or below 2 % of the weight.
[0030]
[Effect of the Invention] According to the manufacture approach of this invention,

production of a bond magnet which has the magnetic properties and the high reinforcement which cannot be attained by the usual shaping approach is possible. Application on current, the OA equipment with which small lightweight-ization progresses, or the motor for power tools which needs a high torque characteristic becomes possible at little cost. Moreover, since the magnetic properties of the isotropic bond magnet manufactured by this invention are not equal to a general-purpose anisotropy Sm-Co bond magnet and do not need Sm, industrial value is large.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the graph which shows the relation between the consistency in this invention, and compressive strength.

[Drawing 2] It is the graph which shows the relation between the mean particle diameter of the magnetic powder in this invention, and compressive strength, a residual magnetic flux density and a maximum energy product.

[Drawing 3] It is the graph which shows the relation between the amount of resin in this invention, and a consistency and compressive strength.

[Drawing 4] It is the graph which shows the relation between the amount of moulding pressure in the conventional 1-time shaping, and a consistency.

[Drawing 5] It is the graph which shows the conventional consistency and the compressive strength in 1-time shaping.

[Drawing 6] It is the graph which shows the consistency in the conventional 1-time shaping, and the relation of a maximum energy product.

[Drawing 7] It is the graph which shows the relation between the consistency in the conventional 1-time shaping, and a residual magnetic flux density.

[Translation done.]

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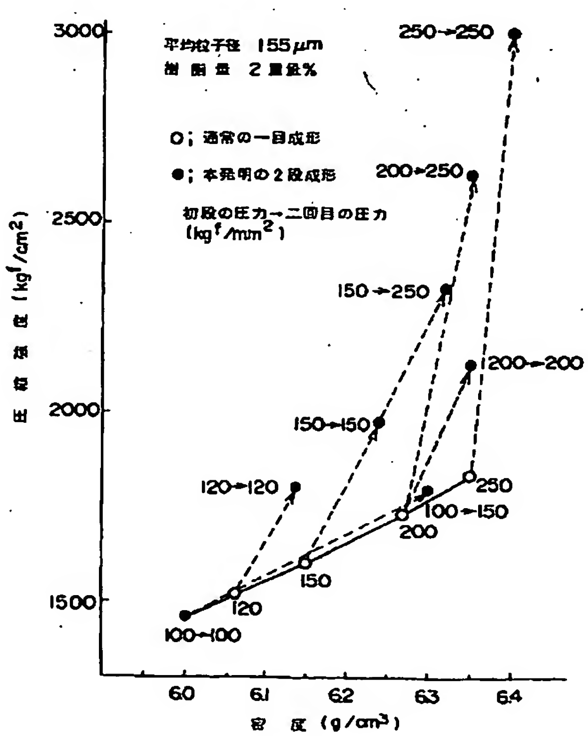
(54)【発明の名称】　等方性ボンド磁石の製造方法

(57)【要約】
【目的】強度が高く、しかも磁気特性が優れた、希土類金属・鉄・コバルト・ボロン系の等方性ボンド磁石を製造する。
【構成】急冷凝固法で作られた組成が希土類金属・鉄・コバルト・ボロン系磁性粉末に樹脂結合剤を付着させ、圧力１２０ｋｇｆ／mm^2 以上で圧縮成形して一旦圧力を解放し、再度前記成形圧力と同等以上の圧力で圧縮して離型した後、加熱して樹脂を硬化する。磁性粉末の平均粒子径を３０～１５５μm、樹脂結合剤付着量を１～３重量%とする。



【特許請求の範囲】

【請求項1】　急冷凝固法で作られた組成が希土類金属・鉄・コバルト・ボロン系の磁性粉末を樹脂結合剤を用いて圧縮成形する方法において、磁性粉末に樹脂結合剤を付着させた粉末を、押型内に充填して圧力１２０ｋｇｆ／mm^2 以上で圧縮成形して一旦圧力を解放し、再度前記成形圧力と同等以上の圧力で圧縮して離型したのち、加熱して樹脂を硬化することを特徴とする等方性ボンド磁石の製造方法。

【請求項2】　平均粒子径が３０～１５５μｍの磁性粉末に樹脂結合剤１～３重量%をコーティングした粉末を用いることを特徴とする請求項１記載の等方性ボンド磁石の製造方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は組成が希土類金属・鉄・コバルト・ボロンよりなるＲＴＢ系磁性粉末を樹脂で結合した等方性ボンド磁石の製造方法に関するもので、モータのステータやロータ等に利用できる。

【０００２】

【従来の技術】ＲＴＢ系の等方性ボンド磁石は、従来のハードフェライト、アルニコ磁石に比べ、優れた磁気特性を持っており、また、異方性のＳｍ－Ｃｏ系ボンド磁石に比べると磁気特性では若干劣るものの、高価なＳｍを用いないことや磁気的異方性を付与しないため、製造工程も簡単になり、コスト面で有利である特徴を持っている。用途としては、電動工具やハードディスク等のモータ用のステータ等に適用されている。

【０００３】等方性ボンド磁石の製造方法は、例えば、特開昭５９－２１１５４９号公報に開示されているように、急冷凝固法と破砕法でＲＴＢ系の磁性粉末を製作し、その磁性粉末に結合剤である有機質材、無機質材、あるいははんだのような低融点金属を混合し、この混合粉を約１１０ｋｇｆ／mm^2 程度の圧力で圧縮成形する。得られる密度は約６．０ｇ／cm^3 程度（密度比８０%程度）である。

【０００４】また、特開平１－２８１７０７号公報記載のように、磁性粉末表面にある種の樹脂をコーティングし、成形時にこの粉末粒子を滑り易く流動性のよい粉末にすることにより、成形体を高密度化して磁気特性を向上させるという提案がある。ところで、等方性ボンド磁石の磁気特性は現状品質でも使用可能であるが、モータの出力向上及び消費電力削減のためには、一層の特性向上が望まれる。そのためには、磁気特性は成形体の密度に依存しているから、成形体に占める磁性粉末の占積率を高めることが必要となる。

【０００５】また一方、モータ用ロータのように運動する部材の用途では、より高い機械強度が要求される。しかしながら、ＲＴＢ系の磁性粉末は、急冷凝固装置を用い作製したリボン状素材をスタンプミル等で破砕したも

のであり、粉末形状は偏平状をしていて、硬さがＨＶ７００～１０００もあり、通常の粉末冶金用粉末のＨＶ１００～２５０に比べて非常に硬い。また、この磁性粉末は活性なＮｄを含んでいるため、小さな粒径の粉末は大気中で酸化反応を生じ易く、粉末の劣化を招くだけでなく、発火の恐れもあるから、市販の粉末の平均粒径は１５５μｍ程度と粗いものになっている。そのため、成形性が著しく悪い粉末であり、高密度化及び強度の向上を困難なものにしていた。

【０００６】

【発明が解決しようとする課題】本発明は、優れた機械的性質と磁気特性とを有する等方性ボンド磁石の製造方法、特に同じ製品密度でも機械的強度を改善し得る成形法を提供しようとするものである。

【０００７】

【課題を解決するための手段】本発明は上記課題を解決するために、急冷凝固法で作られた組成が希土類金属・鉄・コバルト・ボロン系の磁性粉末を樹脂結合剤を用いて圧縮成形する方法において、磁性粉末に樹脂結合剤を付着させた粉末を、押型内に充填して圧力１２０ｋｇｆ／mm^2 以上で圧縮成形して一旦圧力を解放し、再度前記成形圧力と同等以上の圧力で圧縮して離型したのち、加熱して樹脂を硬化することを特徴とする等方性ボンド磁石の製造方法を提供するものである。

【０００８】また、前記の製造方法において、平均粒子径が３０～１５５μｍの磁性粉末に樹脂結合剤１～３重量%をコーティングした粉末を用いることを特徴とするものである。結合剤である樹脂は、エポキシ樹脂が好適である。樹脂は溶剤と共に磁性粉末と混練した後、乾燥してケーキ状とし、それを破砕して成形用の粉末に調製する。

【０００９】また、磁性粉末の平均粒子径を小さくするには、市販の磁性粉末と所定量の樹脂結合剤及び溶剤を粉砕メディアと共に振動ミルのベッセルに入れ、ベッセル内を不活性ガスガス雰囲気に置換した状態で所定時間振動して磁性粉末を粉砕した後、得られる磁性粉末の懸濁液中に含まれる溶剤を不活性ガス雰囲気中で揮発除去して磁性粉末と樹脂からなるケーキ状とし、そのケーキを不活性ガス雰囲気中で破砕して樹脂がコーティングされた磁性粉末とする。

【００１０】成形方法としては、ダイスとパンチによる通常の金型装置を用いて、所定の圧力で最初の成形及び２段目の成形をする方法、ゴム等の弾性体で作られた型の中に粉末を充填し、ＣＩＰにより初段整形して圧力を除いた後、２段目の加圧をして離型する方法、または、テーパ付きの内孔をもつダイスに粉末を充填し、パンチで圧縮した後、この予備成形体をダイスの内孔寸法の大きい側へパンチで移動して初段成形体にかかる圧力を解除した後、２段目の加圧をしてダイスの内孔寸法の大きい側から離型する方法がある。

【0011】成形体の樹脂硬化処理は、温度が約160～180℃で樹脂が硬化する時間保持して行われる。なお、粉末の調整、圧縮成形及び加熱処理は、磁性粉末の酸化をできるだけ防止するために、アルゴンガス等の不活性ガス雰囲気中で行うことが好ましい。

【0012】

【作用】まず、結合剤である樹脂は、その付着方法及び付着量により製品の強度に影響を及ぼす。付着方法としては、粉末混合法と混練によるコーティング法が挙げられるが、コーティング法の方が強度が高く、磁性粉末の表面を覆って酸化防止するので優れている。

【0013】樹脂の付着量は、成形密度と成形体の強度に影響を及ぼす。成形体の強度は、樹脂量が2．0重量%までは付着量にはほぼ比例して上昇するが、2．5重量%より多く付着しても上昇しない。一方、樹脂量が1%未満では成形体にひび割れを生じる。また、成形密度は樹脂量1．5～2重量%で最大値を示し、2重量%を越えると低下傾向となり、3重量%を越えると急激に低下する。よって、樹脂量は1～3重量%、望ましくは1．5～2．5重量%である。

【0014】次に、磁性粉末の粒度は製品の強度及び磁性特性に影響を及ぼす。製品の強度は、市販されている平均粒子径155μmの場合より細かくなるに伴い徐々に高くなって40μmで最大となり、30μmと155μmのときの強度がほぼ同じ値を示し、30μmより細かいと急激に強度が低下する。磁性特性は、平均粒子径155～40μmの間は同等であり、30μm未満で悪化する。よって、磁性粉末の粒子径は、30～155μm、望ましくは40～100μmである。

【0015】次に、成形方法であるが、通常の1回の成形の場合、成形圧力の増加と共に製品の密度が上昇し、それに伴って強度と磁気特性が改善される。しかし、成形圧力250kgf／mm^2 以上にしても密度は上昇しない。一方、2段成形法であるが、加圧力の増加によって密度が上昇し、それに伴って強度及び磁気特性が改善されるのは前者と同様である。しかし、製品の強度は通常の1回成形では得られない高い特性が得られる。ここで重要なことは、成形圧力がある加圧力以上でないと2段成形の効果は全く認められないことである。すなわち、初段の成形圧力が110kgf／mm^2 以下では1回成形の場合と何ら変わらない。初段の成形圧力120kgf／mm^2 以上で、2段目の成形圧力も初段と同等あるいはそれ以上になって、強度向上の効果が現れる。例えば、通常の1回成形で圧力250kgf／mm^2 で得られる密度が6．35g／cm^{3}で強度が1830kgf／cm^2 であるのに比べ、初段と2段目をそれぞれ200kgf／mm^2 で成形すると密度が6．35g／cm^3 で強度が2130kgf／cm^2 、初段と2段目をそれぞれ250kg／mm^2 で成形すると6．40g／mm^3 で強度が3000kgf／cm^2 となる。

【0016】このことは、樹脂が被覆された偏平状の磁性粉末を加圧成形する過程から考察すると、加圧力の増加につれ、まず粉末間の空間が次第に減少し密度が上昇する。さらに加圧力を上昇すると、一部の粒子が破砕されながら更に密度が上昇するが、偏平粒子がランダムに配列したブリッジ状態になっており、加圧力を増大してもそれ以上は密度が上昇しなくなる。その後、圧力を解放すると、成形体はスプリングバックして粒子間に僅かの隙間を生じる。次いで2段目の加圧をすると、偏平粒子の多くは、加圧方向に対し直角な向に配列されて密度が上昇し、粒子間の接触面積が増加することにより強度が高くなるものと推察される。

【0017】

【実施例】〔実施例1〕用いた磁性粉末は、鉄を67．0重量%、コバルトを5．2重量%、ネオジウムを24．6重量%、及びボロンを1．7重量%含有する急冷凝固法で作られたもので、平均粒子径は155μmである。

【0018】樹脂コーティングは、溶剤にエポキシ樹脂を溶かし、この溶液と磁性粉末をニーダーで混練した。その後、アルゴンガスで置換した恒温槽を用い溶剤を乾燥させ、磁性粉末表面をエポキシ樹脂でコーティングした。樹脂の量は2．0重量%である。この粉末を用い、初段の圧力を100～300kgf／mm^2 で成形した試料を作製した。

【0019】次に、初段で使用した金型より内孔が少し大きい金型を用い、初段の圧力を100～250kgf／mm^2 で成形した試験片を圧力100～250kgf／mm^2 で2段目の成形を行った。その後、1回成形した試料（比較例）と2段成形した試料のそれぞれをアルゴンガスで置換した恒温槽で温度160℃で1時間、更に温度180℃で1時間加熱して樹脂硬化を施した。試料寸法は直径11．3mm、高さ10mmである。

【0020】次に、各試料について密度、磁気特性として残留磁束密度と最大エネルギー積、及び試料軸方向の圧縮強度を測定した。圧縮強度は、圧縮試験機を用い、圧縮速度0．5mm／分で試験片を圧縮したときの応力一歪み曲線図における最大値である。まず、比較例の1回成形の試料の特性について、図4に成形圧力と密度の関係、図5に密度と圧縮強度の関係、図6に密度と最大エネルギー積の関係、図7に密度と残留磁束密度の関係を示す。

【0021】図4から、成形圧力250kgf／mm^2 で密度が最大値6．35g／cm^{3}となり、それ以上圧力を加えても密度が上昇しないことが判る。図5から、密度と圧縮強度は相関関係にあり、圧縮強度の最大値は1830kgf／cm^2 である。図6及び図7から、磁性特性は密度が高い程よい性質を示すことが判る。

【0022】次に、図1は、2段成形法により作製した試験片の強度について本発明の効果を示したものであ

る。なお、比較のため図５に示した通常の１回成形の結果も併記した。白丸は通常の１回成形による値を示し、黒丸は２段成形法の値である。２段成形法の成形圧力は、矢印の左側に初段の圧力、矢印の右側に２段目の圧力を示している。

【００２３】初段の圧力が１００ｋｇｆ／mm^2 の試験片は、２段目の圧力が１５０ｋｇｆ／mm^2 でも通常の成形方法で達成できる強度であり、本発明の効果がない。しかし、初段の圧力が１２０ｋｇｆ／mm^2 以上になると強度は飛躍的に向上する。ここで特記すべきは、初段の成形圧力１５０ｋｇｆ／mm^2 、２段目の圧力１５０ｋｇｆ／mm^2 の試験片は、通常の成形方法で圧力２００ｋｇｆ／mm^2 で作製した試験片と密度は同じであるにもかかわらず強度は高い値を示しており、さらに、通常の成形方法の２５０ｋｇｆ／mm^2 よりも高い値である。

【００２４】また、初段と２段目ともに２５０ｋｇｆ／mm^2 で成形したものは、従来法で得られる圧縮強度の最大値の１．６倍である３０００ｋｇｆ／ｃm^2 が得られる。

〔実施例２〕実施例１で用いた平均粒子径１５５μｍの磁性粉末と、溶剤に溶かしたエポキシ樹脂及び粉砕用のボールを遊星ボールミルに入れ、ミル内をアルゴンガスで置換して密封した状態で所定時間運転した後、アルゴンガスで置換した恒温槽内に取り出して溶剤を乾燥させ、ケーキ状の粉末をアルゴンガス中で破砕してエポキシ樹脂でコーティングされた平均粒子径の異なる磁性粉末を作製した。樹脂の量は２．０重量%である。

【００２５】次に、可変雰囲気成形プレスを用い、金型をアルゴンガス雰囲気中に入れて各粉末を２段成形法で圧縮成形した後、実施例１と同様に樹脂硬化処理をした。成形圧力は初段、２段目共に２５０ｋｇｆ／mm^2 である。得られた試料について圧縮強度、残留磁束密度及び最大エネルギー積を測定した。

【００２６】図２に平均粒子径と各測定結果の関係を示す。圧縮強度は、粒径が小さくなるのに伴い次第に高くなり、平均粒子径が４０μｍのとき最大値を示す。４０μｍより粒径が小さくなると強度が低下して平均粒子径が３０μｍと１５５μｍはほぼ同じ値を示している。磁性特性は、平均粒子径が１５５～４０μｍの間は同等な値を示し、４０μｍより小さくなると悪化する傾向を示している。

【００２７】このことから、磁性粉末の平均粒子径は、市販のままの１５５μｍでも良好な特性が得られるが、より高い強度を得るには、平均粒子径５０μｍ前後が良好であることが判る。

〔実施例３〕平均粒子径１５５μｍの磁性粉末を用い、エポキシ樹脂のコーティング量が異なる粉末を実施例１と同様な方法で作製した。

【００２８】次に、樹脂量が異なる各粉末を初段及び２段目共に１５０ｋｇｆ／mm^2 の圧力で成形した後、実施例１と同様に樹脂硬化処理して試料とし、密度と圧縮強度を測定した。図３に樹脂量と密度及び圧縮強度の関係を示す。樹脂量が１重量%より少ないと成形体にひび割れを生じてしまう。

【００２９】密度は、樹脂量が１．５～２重量%の間で最大値を示し、３重量%を越えると低下が著しくなる。圧縮強度は、樹脂量を増加すると上昇し、２．５重量%で最大値を示し、それ以上添加しても効果がない。このことから、樹脂量は、ひび割れが出ない１重量%以上は必要であり、密度が著しく低くしない３重量%までである。好ましくは、２重量%前後であることが判る。

【００３０】

【発明の効果】本発明の製造方法によれば、通常の成形方法では達成することのできない、磁気特性及び高い強度を有するボンド磁石の作製が可能である。現在、小形軽量化が進むＯＡ機器、あるいは高トルク特性を必要とする電動工具用モータへの適用が、少ないコストで可能となる。また、本発明で製造する等方性ボンド磁石の磁気特性は、汎用の異方性Ｓｍ－Ｃｏボンド磁石に匹敵するものであり、Ｓｍを必要としないので工業的価値は大きい。

【図面の簡単な説明】

【図１】本発明における密度と圧縮強度の関係を示すグラフである。

【図２】本発明における磁性粉末の平均粒子径と、圧縮強度、残留磁束密度及び最大エネルギー積との関係を示すグラフである。

【図３】本発明における樹脂量と、密度及び圧縮強度との関係を示すグラフである。

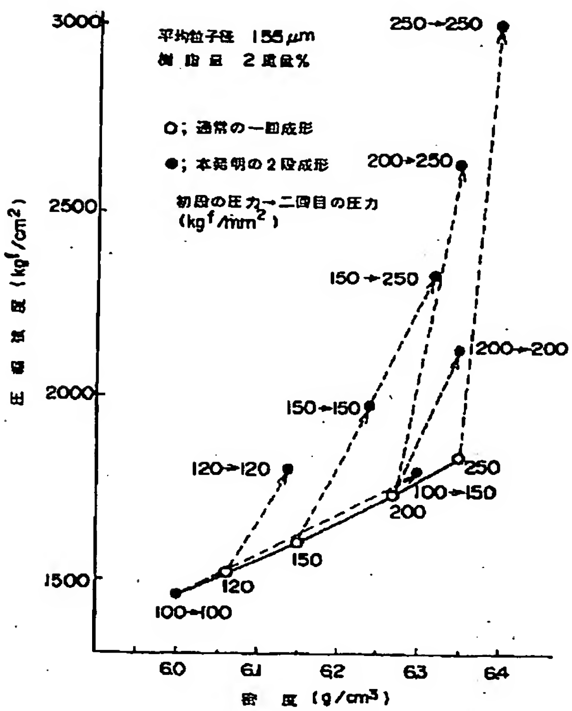
【図４】従来の１回成形における成形圧量と密度の関係を示すグラフである。

【図５】従来の１回成形における密度と圧縮強度を示すグラフである。

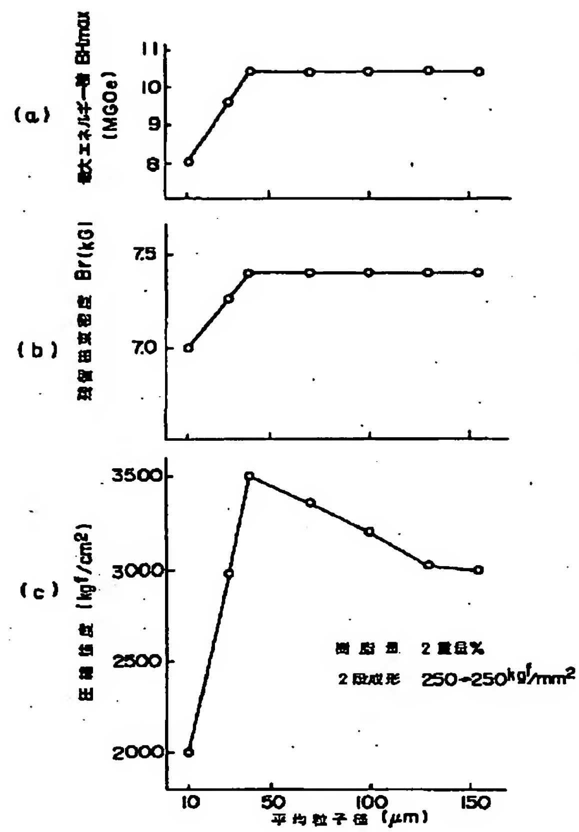
【図６】従来の１回成形における密度と最大エネルギー積の関係を示すグラフである。

【図７】従来の１回成形における密度と残留磁束密度の関係を示すグラフである。

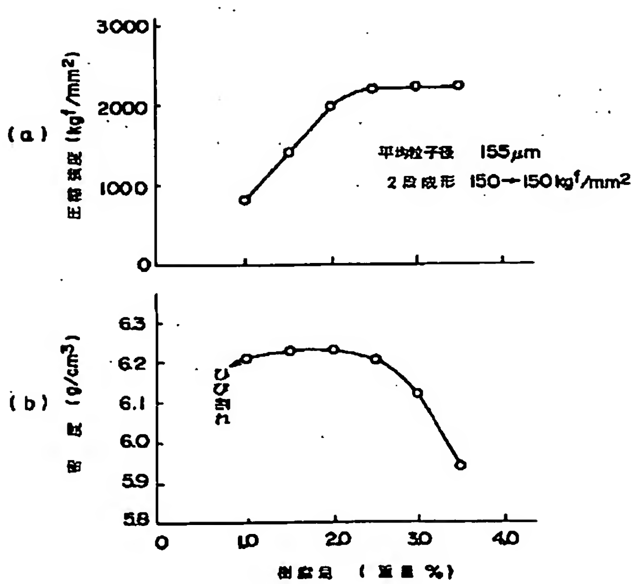
【図1】


平均粒子径 155μm
樹脂量 2重量%
○; 通常の一回成形
●; 本発明の2段成形
初段の圧力→二回目の圧力
(kgf/mm²)
250→250
200→250
150→250
200→200
150→150
120→120
100→150
250
200
150
120
100→100
圧縮強度 (kgf/cm²)
密度 (g/cm³)

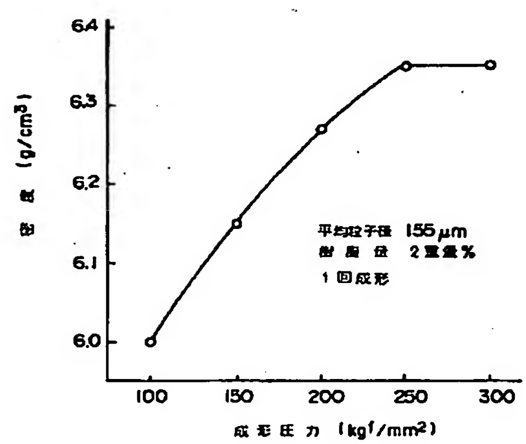
【図2】


(a)
最大エネルギー積 BHmax (MGOe)
(b)
残留磁束密度 Br(kG)
(c)
圧縮強度 (kgf/cm²)
樹脂量 2重量%
2段成形 250→250kgf/mm²
平均粒子径 (μm)

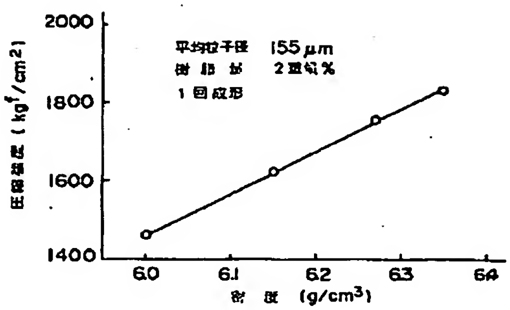
【図3】


(a)
圧縮強度 (kgf/mm²)
平均粒子径 155μm
2段成形 150→150kgf/mm²
(b)
密度 (g/cm³)
樹脂量 (重量%)

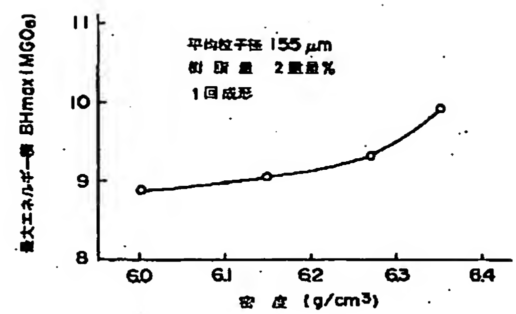
【図4】


密度 (g/cm³)
平均粒子径 155μm
樹脂量 2重量%
1回成形
成形圧力 (kgf/mm²)

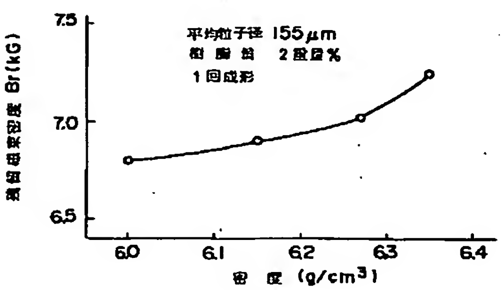
【図5】


平均粒子径 155μm
樹脂量 2重量%
1回成形
圧縮強度 (kgf/cm2)
2000
1800
1600
1400
6.0
6.1
6.2
6.3
6.4
密度 (g/cm3)

【図6】


平均粒子径 155μm
樹脂量 2重量%
1回成形
最大エネルギー積 BHmax (MGOe)
11
10
9
8
6.0
6.1
6.2
6.3
6.4
密度 (g/cm3)

【図7】


平均粒子径 155μm
樹脂量 2重量%
1回成形
残留磁束密度 Br (kG)
7.5
7.0
6.5
6.0
6.1
6.2
6.3
6.4
密度 (g/cm3)